Space Weather Technical Forecast

Issued on Wednesday 25 December 2024 at 00:13 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Further M-flares expected. G1/Minor Geomagnetic Storms likely 25-26 Dec. Chance of Active fluence.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate with several M-class flares observed, mostly from the complex of spots near south centre disc. The peak flare measured at M4.7 was observed from AR3932 at 24/0019 UTC.

There are now eleven sunspot regions on the visible disc. The region on the northeast limb has been numbered AR3938, but is currently still too close to the limb for an accurate analysis. South centre disc remains of interest on the disc, containing a cluster of three of the larger regions (AR3928, AR3932 and AR3933). However, AR3928 and AR3932 both appear to have undergone a reduction in magnetic complexity, with the delta spot pulling apart in AR3932. AR3936 saw growth in recent hours, becoming the largest region on the disc, but so far with a reasonably simple magnetic layout. Other remaining regions are mostly smaller and simpler.

No Earth directed CMEs were observed in solar imagery in the last 24 hours.

Solar Wind / Geomagnetic Activity: Solar winds, as observed at L1 by ACE, showed a waning connection to CH01/-. Wind speeds declined from strong levels, around 600 km/s, to elevated levels, near 500 km/s. Density was below average. The Interplanetary Magnetic Field, Bt, was weak at 6nT or below. The north-south component, Bz, varied weakly between +/-6nT. Phi angle was mainly negative (towards the Sun). Geomagnetic activity was Quiet to Unsettled (Kp1-3).

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) was well below the S1/Minor Radiation Storm threshold, but slightly elevated above normal background levels, on a slowly declining trend. High energy electron flux (greater than 2MeV) observed by GOES16 was at moderate levels. The associated 24-hour fluence was below the Active (1e8 integrated flux) threshold on a slightly declining trend. The 25/0000UTC observation was 2.69e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Further M-class flares are expected, with a slight chance of isolated X-class flares throughout.

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Solar Wind / Geomagnetic Activity: A CME from 23 Dec may give a glancing blow at Earth on Day 1 or Day 2 (25-26 Dec), with some uncertainty in the timing of this feature. No other CMEs currently feature in the forecast, although confidence in this aspect of the forecast is lower than usual. Solar winds are elevated but slowly declining due to a waning connection to CH01/-. However, there is also the possibility of some further High Speed Stream (HSS) activity later in the period.

Geomagnetic activity is expected to be mainly Quiet to Unsettled at first. Later Day 1 into Day 2, peak G1-G2/Minor-Moderate Storm levels are possible, with a slight chance of G3/Strong Storm intervals, due to potential CME influence. By Days 3 and 4 (27-28 Dec), mainly Quiet to Unsettled activity is forecast, but with lower confidence given the uncertainty in the CME forecast.

Energetic Particles / Solar Radiation: There is a slight chance of S1/Minor Radiation Storm or greater enhancements during the period. In the absence of any further notable flares, ongoing slightly enhanced high-energy proton counts should ease towards normal background levels in the coming days.

The high energy electron forecast carries lower than average confidence due to the uncertainty in the CME forecast. However, there is a chance of exceeding Active on Day 1, before any CME arrival, reducing to a slight chance on Days 2-3 (26-27 Dec), this increasing a little by Day 4 (28 Dec).

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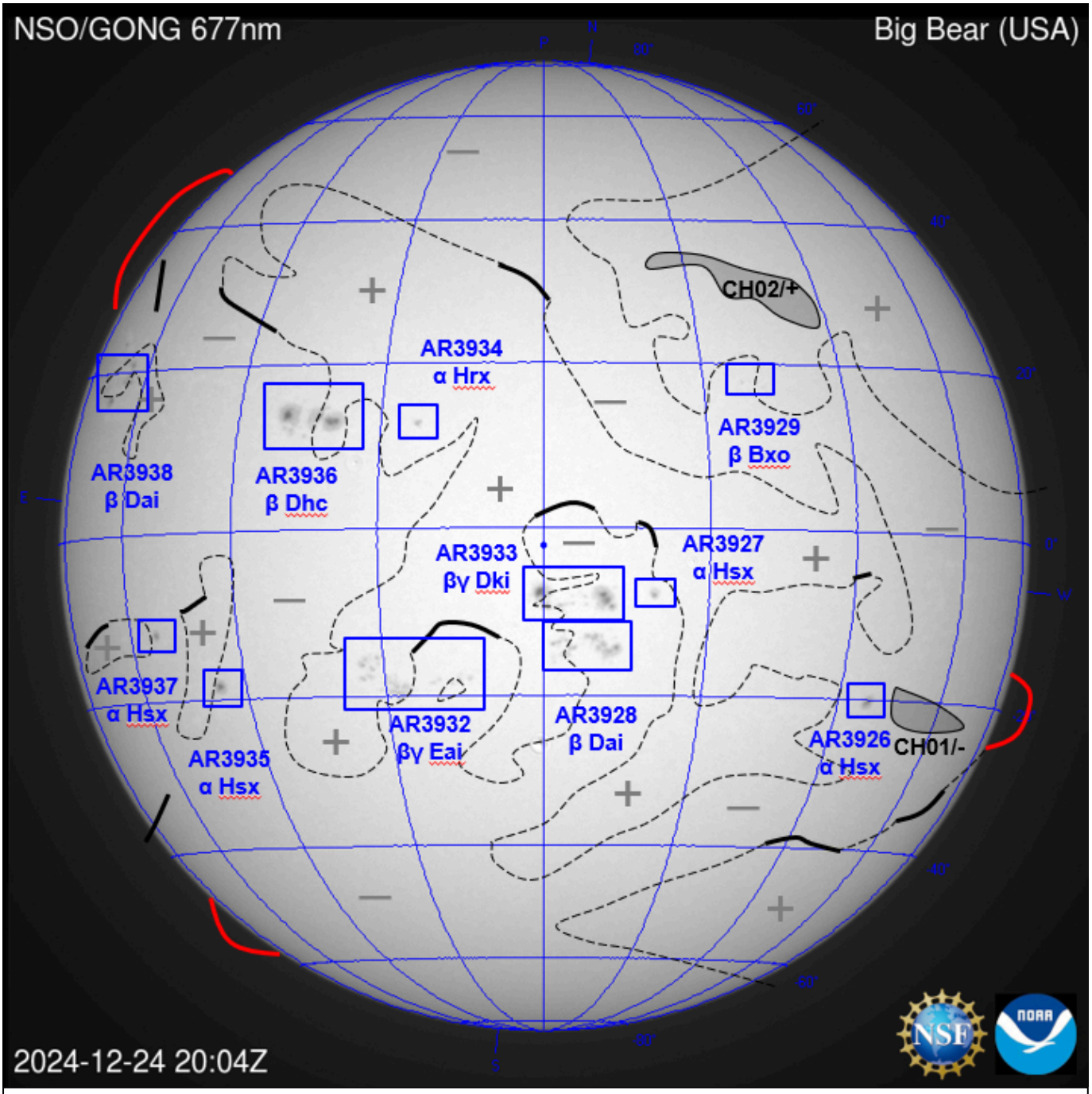
Figure 1: Solar synoptic map valid 24/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms

A filament lift-off from the northeast disc late on 20 Dec is now thought to have missed Earth. On 23 Dec the M8.9 flare from AR3923 and a nearby, sympathetic filament lift-off in the southeast disc resulted in a moderately fast CME. The bulk of the ejecta is modelled to pass below the Earth-Sun line, however a glancing blow is considered possible on Day 1 or Day 2 (25-26 Dec). Uncertainty in the timing of this feature is increased by Enlil showing a High Speed Stream (HSS) at the same time, with no significant source coronal hole visible in GOES SUVI-195 imagery. That said, there is the possibility of a coronal hole obscured by magnetic looping north of the AR3933/AR3928/AR3932 complex. No other Earth-directed CMEs currently feature in the forecast, however due to the number of recent CMEs in solar imagery, confidence in this aspect of the forecast is lower than usual.

Solar winds are elevated but slowly declining due to a waning connection to CH01/-. A further enhancement is possible, but unlikely on Days 2 and 3 (26 and 27 Dec) from CH02/+ located in the northwest disc. However, as discussed above, there is also the possibility of an obscured coronal hole giving a HSS as modelled by Enlil, but perhaps slightly later in the period.

Geomagnetic activity is expected to be mainly Quiet to Unsettled at first. Later Day 1 into Day 2, peak G1-G2/Minor-Moderate Storm levels are possible, with a slight chance of G3/Strong Storm intervals, due to potential CME influence. By Days 3 and 4 (27-28 Dec), mainly Quiet to Unsettled activity is forecast, but with lower confidence given the uncertainty in the CME forecast.

Geomagnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	**G1 to G2**	No	50	60	10	5
Strong	**G3**	No	5	10	1	1
Severe	**G4**	No	1	1	1	1
Extreme	**G5**	No	1	1	1	1

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Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R⊙ (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed (km/s)	Estimated Arrival Time (UTC)	Comments
23/1550 UTC	Partial	Flare and Filament	SE disc (AR3932)	780	25/1800 UTC	Possible glancing blow, low confidence on timings. +/- 12 hours from Estimated Arrival Time.

Figure 2: MOSWOC Enlil showing a potential CME arrival later on 25 Dec, but this mixed with a HSS of uncertain origin, introducing uncertainty in the timing.

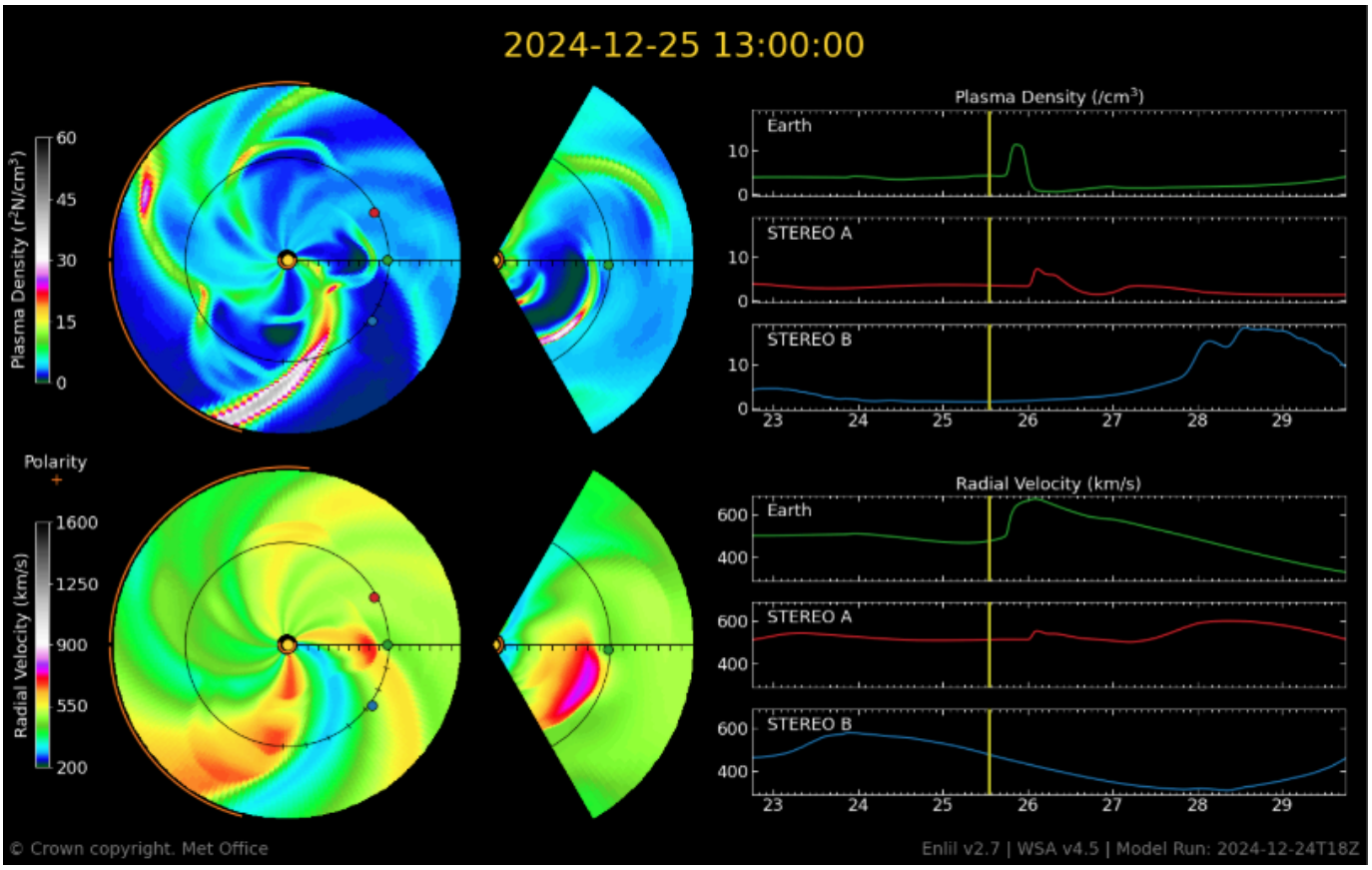

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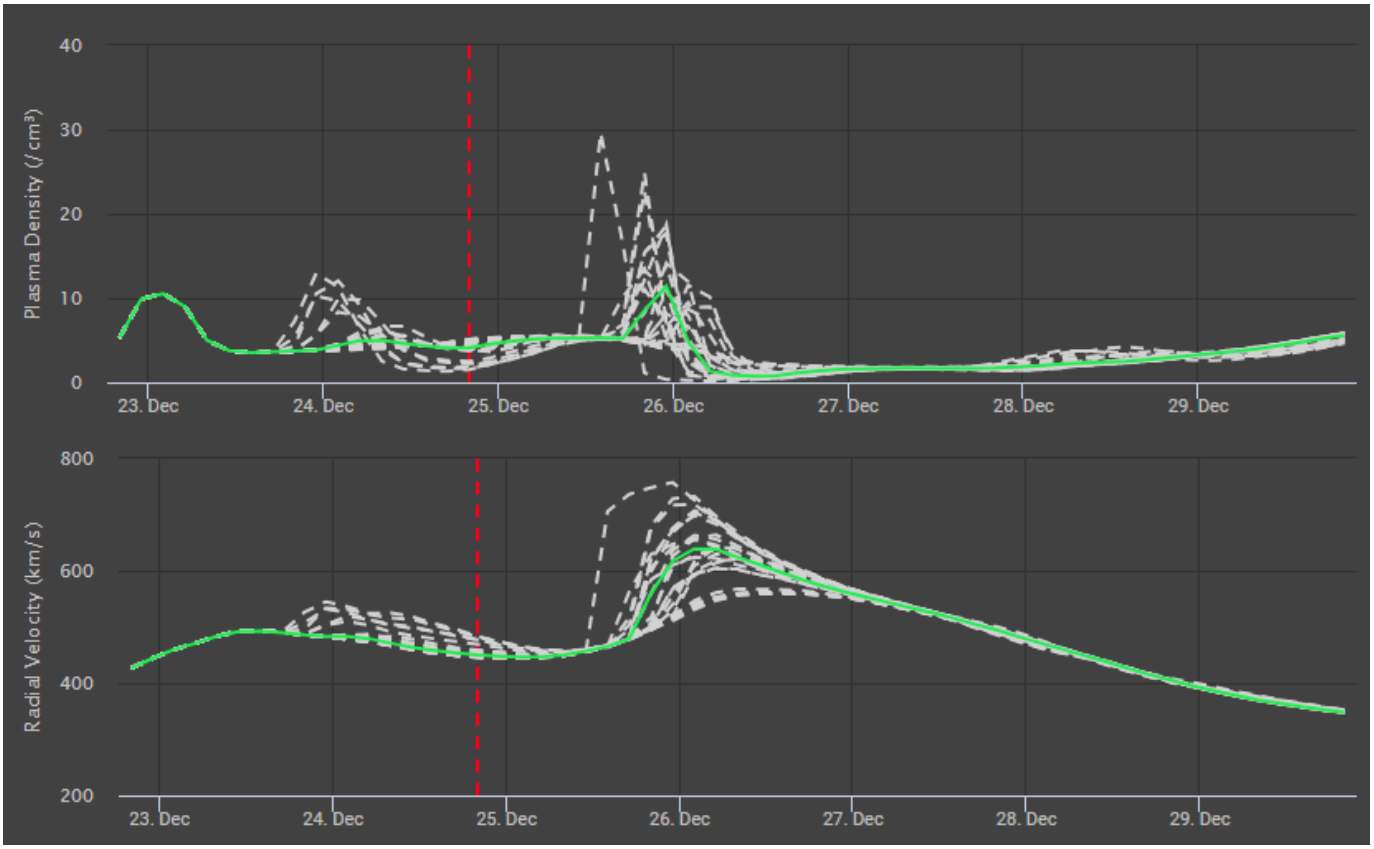
Figure 3: Enlil ensemble, showing the likely CME arrival later 25 Dec or early 26 Dec, but the timing uncertainty is perhaps broader than shown by the ensemble.



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Radio Blackouts - X-Ray Flares

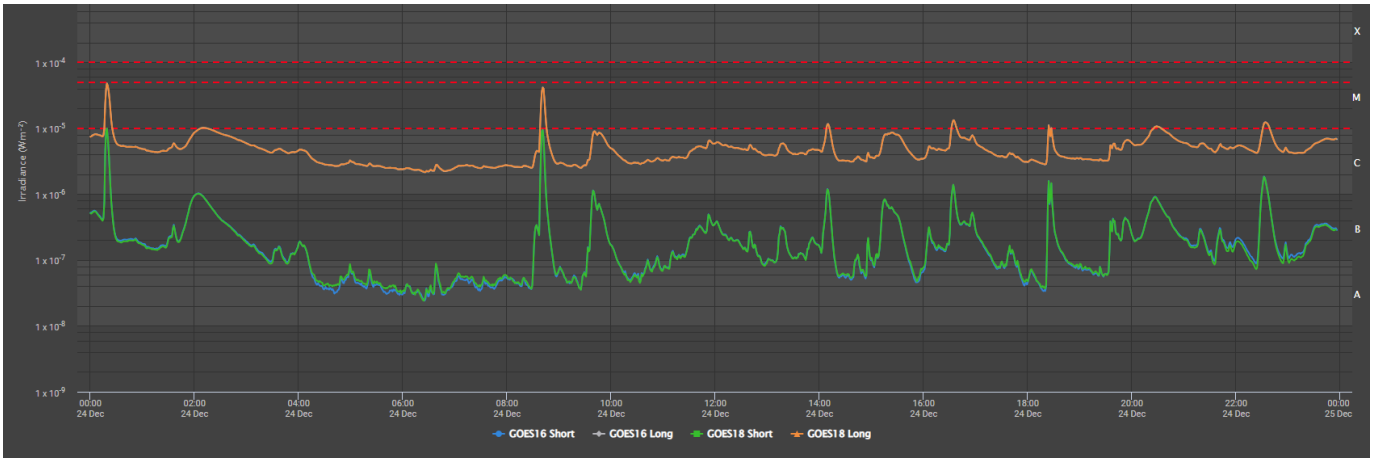
Solar activity has been Moderate with several M-class flares observed, mostly from the complex of spots near south centre disc. The peak flare measured at M4.7 was observed from AR3932 at 24/0019 UTC. There are now eleven sunspot regions on the visible disc, with AR3930 rotating off and the new region in the southwest fading. The region on the northeast limb has been numbered AR3938, but is currently still too close to the limb for an accurate analysis. South centre disc remains of interest on the disc, containing a cluster of three of the larger regions (AR3928, AR3932 and AR3933). However, AR3928 and AR3932 both appear to have undergone a reduction in magnetic complexity, with the delta spot pulling apart in AR3932. AR3936 saw growth in recent hours, becoming the largest region on the disc, but so far with a reasonably simple magnetic layout. Other remaining regions are mostly smaller and simpler.

There are signs of a new region rotating onto the southeast limb, perhaps returning Ex-AR3912, which was previously responsible for X-class flare activity earlier in December and was perhaps the source of a large far-sided CME on 17 Dec. If the sunspot has maintained its complexity it could contribute to higher flare probabilities in the upcoming days although far-side sounding imagery does suggest this region may have faded somewhat.

The assessment of any new regions notwithstanding, flare risk looks to remain elevated during the period and further M-class flares are expected, with a slight chance of X-class flares maintained throughout.

X-Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 (M Class)	Yes	80	80	80	80
Very Active	R3-R5 (X Class)	No	10	10	10	10

Figure 4: X-ray flux at GOES16 and 18, showing several M-class flares in the last 24 hours.



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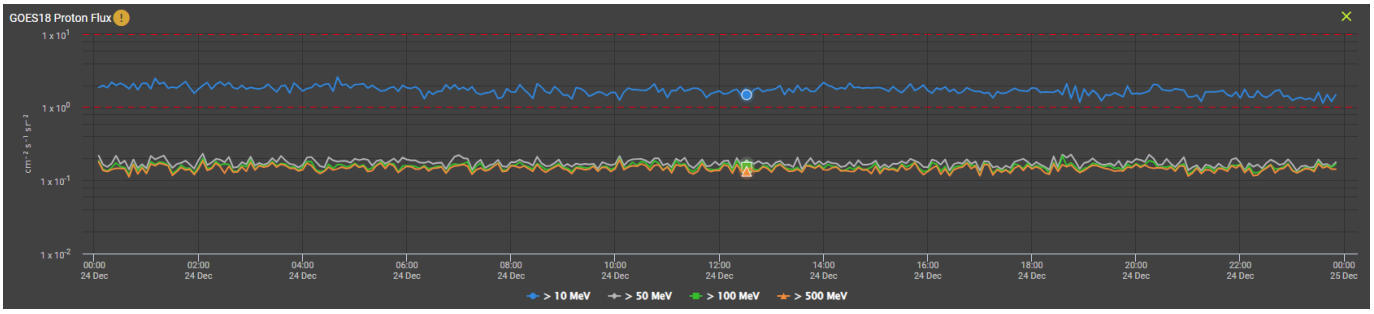
Solar Radiation Storms (High Energy Protons)

The source of the currently observed slight enhancement in the near-Earth environment is somewhat uncertain, but a far-sided source on 19 Dec seems most likely. Given that this feature is now likely to be well onto the far side, further enhancement from this source is now considered unlikely. High energy proton counts are slowly declining and should continue to ease towards typical background values in the coming days in the absence of significant flaring. There is a slight chance of S1/Minor Solar Radiation storms or greater, should any significant flares occur, this increasingly slightly as the larger regions on the facing disc move into more favourable western locations for connection with Earth.

Radiation Storms Probability (Exceedance)	Level ($cm^{-2}sr^{-1}s^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	15	15
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 5: Proton flux at GOES18, with the 10MeV flux above normal background levels but well below the S1 threshold.



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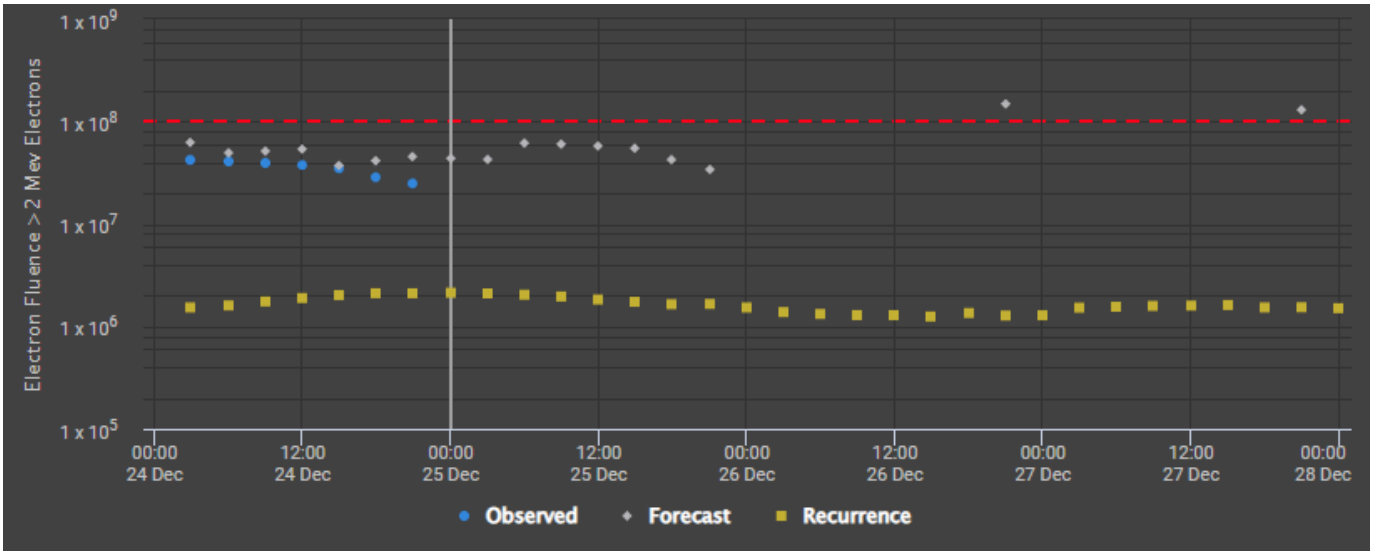
High Energy Electrons (≥ 2MeV)

Current high energy electron flux has been at moderate levels in the last 24 hours. As solar wind pressure from CH01/- continues to ease, diurnally high electron flux levels are possible on Day 1 (25 Dec). However, the likely arrival of a CME later Day 1 or early Day 2 (25-26 Dec) may temporarily suppress electron counts, before potentially increasing again later in the period, depending on how much geomagnetic activity the CME causes.

Electron fluence has been slowly declining over the last 24 hours, and is most likely to remain below the Active threshold for much of the period. However, there is a chance of exceeding Active on Day 1, before any CME arrival, reducing to a slight chance on Days 2-3 (26-27 Dec), this increasing a little by Day 4 (28 Dec), but with low confidence. MOSWOC REFM is forecasting an increase above Active by Day 2, but this is considered overdone, as REFM will not be taking any CME arrival into account.

GEO Electron Environment	Level ($cm^{-2}sr^{-1}$ day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ 1×10^8	No	30	20	10	30
Very Active	≥ 2 MeV ≥ 1×10^9	No	1	1	1	0

Figure 6: MOSWOC REFM showing an increase above Active, which is likely to be overdone.



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